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30 JAN 1985

MEMORANDUM FOR: (See Distribution List)

FROM: [redacted] 25X1
Chief, Strategic Resources Division
Office of Global Issues

SUBJECT: Climate Change in the Major Grain Areas of the USSR and Grain Production Estimates for 1986-1990 [redacted] 25X1

1. The attached memorandum presents the results of a climate study of the major grain growing regions of the USSR during the period 1920 - 1984, and projects grain production for the 1986 - 1990 period based on "favorable", "most likely", and "unfavorable" weather scenarios. [redacted] 25X1

2. This assessment was prepared by [redacted] 25X1 Agricultural Assessments Branch, Strategic Resources Division, Office of Global Issues. [redacted] 25X1

3. Comments and questions are welcome and may be addressed to the Chief, Agricultural Assessments Branch, on [redacted] 25X1
25X1

[redacted]

Attachment:
Climate Change and Grain Production in the USSR, 1920 - 1990 [redacted] 25X1
GI M 85-10019, January 1985 [redacted] 25X1

[redacted] 25X1

SECRET

SUBJECT: Climate Change in the Major Grain Areas of the USSR and Grain Production Estimates for 1986 - 1990 [redacted] 25X1

OGI/SRD/AAB [redacted] (30 January 1985) 25X1

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Central Intelligence Agency

Washington, D.C. 20505

DIRECTORATE OF INTELLIGENCE

30 JAN 1985

Climate Change and Grain Production in the USSR, 1920 - 1990

Summary

Based on our analysis of long term weather patterns and trends in fertilizer deliveries to agriculture, we estimate that Soviet grain production during the 1986-90 period most likely will average 195 million tons annually--about 60 million tons below target. With favorable climate and fertilizer delivery at planned levels, we believe Soviet grain production could average 221 million tons. With adverse weather conditions similar to the 1961-65 period and only a slight increase in fertilizer delivery above recent levels, we estimate that grain production could average as low as 165 million tons annually. As with all statistical assessments, there is a range of error associated with the three preceding scenarios. However, we calculate that there is a 95% probability that the average for each scenario is accurate to ± 15 million tons. In all cases, we assume harvested area will approximate 124 million hectares, roughly equal to the annual average hectarage for 1979-83. [redacted] 25X1

Precipitation and temperature records of the grain area show a definite improvement of the climate overall since the 1930s. Although it is impossible to predict with certainty whether the climate will continue to improve in the future, trend and projected increases in atmospheric carbon dioxide suggest that temperatures will continue to increase in the grain area. We also expect precipitation to remain about the same as the present level or increase slightly during the rest of the eighties. In our judgment, it is highly unlikely that the precipitation regime of the grain area will revert to the drier pre-1960s levels. [redacted] 25X1

Analysis of regional precipitation and temperature pattern changes during the last ten years suggest problems for the Soviets in some grain areas. Temperature increases will lengthen the growing season in the north, but will exacerbate the dry conditions in the Southern Urals, lower Volga and Kazakhstan--areas which account for 20 percent of Soviet grain production. [redacted] 25X1

This memorandum was prepared by [redacted] Agricultural Assessments Branch, Strategic Resources Division, Office of Global Issues. Comments may be directed to [redacted] Chief, Strategic Resources Division, [redacted] 25X1 25X1 25X1 25X1

[redacted]

GI M 85-10019

SECRET

Climate Change and Grain Production in the USSR, 1920 - 1990

This study presents the results of an analysis of weather conditions in the major grain-growing regions of the USSR during the period 1920 - 1984. The study identifies climatic change during this period and projects the potential effects of climate change and technology on Soviet grain production through 1990. 25X1

Background

The precipitation and temperature regimes of the major grain-growing regions of the Soviet Union were analyzed using a computerized weather database compiled from data recorded at 66 Soviet climatological stations.[1] The stations are distributed nearly evenly across the grain-growing regions of the USSR (Figure 1). Of the 66 stations, 21 provided data from 1920 to 1949, all provided data from 1950 to 1974, and 36 provided data from 1975 to 1984. 25X1

Good correspondence between annual averages obtained from the sets of 21, 36, and 66 stations for the period 1950 to 1974 allowed us to use the data from only 21 stations for 1920 - 1949 and 36 stations for 1975 - 1984 with confidence. The grain region's annual temperature and precipitation averages were obtained by weighting each station's average by the fraction of total grain area within a surrounding polygon.[2] The annual precipitation averages of the 21 and 36 station sets were within 2-3 percent of the annual averages of the 66 stations, and the five-year averages of the 21 and 36 sets were within 1-1.5 percent of the 5-year averages of the 66 stations (Table 1). Even better correspondence was obtained in the temperature comparisons. 25X1

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1 The information sources for this database are "World Weather Records" published by the old US Weather Bureau and "Monthly Climatic Data for the World" published by the National Oceanographic and Atmospheric Administration (NOAA). 25X1

2 A standard technique called the Thiessen polygon method was used. The technique assumes that the precipitation at any station can be applied halfway to the next station in any direction. The polygons are formed by the perpendicular bisectors of the line joining nearby stations. The grain area in each polygon is used to weight the precipitation amount (or temperature) of the station in the center of the polygon. 25X1

25X1

GI M 85-10019

Climatic Change

Precipitation

A general trend of increasing precipitation, starting in the 1930s, is evident from the study of 5-year precipitation averages (Figure 2). Although precipitation has varied greatly from year to year, on average it has increased about 20 millimeters (mm) per decade since the 1940s. The 1970s received about 476mm, 25mm more than the 1960s, and 71mm (almost 3 inches) more than the dry 1930s. The last 5-year average (1980-1984) shows a slight decrease to 470mm, but is still considerably above the long-term (1920-1984) average of 435 mm. The precipitation record shows a definite improvement in the climate of the grain growing areas. [redacted] 25X1

It is not possible to determine with certainty whether the precipitation regime will improve in the next five years. Nevertheless, we can postulate with a fairly high degree of confidence that the 1986 - 1990 average should not depart greatly from the 1980-1984 average even though year-to-year precipitation may continue to vary widely. Analysis of the 1920-1984 records show that each 5-year average differed from the previous period by an average of about 18mm, and in the extreme (as in the 1930s) by about 40mm. Because precipitation for the 1980-1984 period averaged 470mm, it follows that the precipitation average for the 1986-1990 period might range anywhere from 430 to 510mm, but more likely will fall somewhere between 450 and 490mm. [redacted] 25X1

Analysis of the grain area shows a regional change in precipitation during the last 10 years (1975-1984) compared to the 1950-74 period (Figure 3). Most of the grain area experienced an increase in precipitation. The increase was as much as 75mm in parts of European RSFSR and eastern Ukraine. Decreases of about 25mm or more have occurred in some important grain producing areas of the southern Urals and western and eastern Kazakhstan. [redacted] 25X1

Temperature

Analysis of data from the Soviet climatological stations shows a gradual temperature increase in the grain-growing region, from a 5-year average of about 4.4°C in the 1940s to about 5.4°C for the 1980-1984 period (Figure 4). The 1980-1984 period was the warmest recorded in our weather database, and also contained the year (1983) with the highest average annual temperature (6.5°C). Part of this long-term temperature increase may reflect urbanization (i.e., increased pollution and city heat-island effects). The rest of this increase may represent the real increase in air temperature worldwide that is generally attributed to a rise in atmospheric carbon dioxide.[3] [redacted] 25X1

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3 Changing Climate, National Academy of Science, National Academy Press, 1983. [redacted] 25X1

Figure 5 shows the regional change in annual temperature during the last 10 years (1975-1984) compared to the 1950-1974 period. Temperature increases on the order of 0.5 to 1.0 C are evident over most of the grain area. A climatic increase in temperature usually causes a lengthening of the growing period, which in the future may permit additional areas in Siberia and northern European RSFSR to come under cultivation, especially with the hardier rye varieties that are already showing success. On the other hand, future temperature increases in the southern Urals, lower Volga, and Kazakhstan would further exacerbate the already adverse dry climate there. 25X1

For the next five year period we expect an increase in the average temperature over the long term (1920-1984) mean (4.7°C) as a result of a continued increase of carbon dioxide in the atmosphere. The temperature increase however, may not be as drastic as that experienced during 1980-84 compared to 1975-79. Continuation of the trend of 5 year averages from the 1940s to the present would place the average 1986-90 temperature between 5.0° to 5.2°C. We believe this is probably an accurate representation of the long-term effect of carbon dioxide on temperature. 25X1

Forecasts of Soviet Grain Yields for the 1986-1990 Period

Average grain yields for the 1986-1990 period were estimated using a regression model (see the appendix for a discussion of the model). To derive these estimates, we examined various factors which influence grain production. Statistical analysis showed that weather factors such as precipitation, temperature, and the level of fertilizer deliveries to agriculture adequately capture the variability in Soviet grain yields. As a result, we developed a set of weather and fertilizer delivery scenarios to use in estimating future Soviet grain production. 25X1

Selection of Weather Scenarios

Variation in precipitation is the most important single cause of grain yield variation. Based on precipitation trends (Figure 2 and Table 1), we estimate with confidence that during 1986-1990 the average amount of precipitation in the grain area will most likely range between 450 to 490 mm. The trend in precipitation has been upward from the 1950s to the late 70s. Although precipitation levels have decreased slightly in the last 5 years, it is too early to tell whether this is the beginning of a downward trend. The general upward trend in precipitation is consistent with the findings of the National Academy of Science[4] which projects that mean global precipitation will increase due

[4] Changing Climate, National Academy Press, 1983. 25X1

to increases in atmospheric carbon dioxide. Nevertheless, the Academy cannot predict the magnitude and/or location of such increases. It is unlikely that the climate would suddenly revert to the lower precipitation levels of the 1940s and 1950s, although sudden shifts in precipitation levels--as happened in the 1930s--are still possible. 25X1

Based on historical precipitation levels, we chose three weather scenarios to use in our estimation process.

- For the most likely weather scenario of the 1986-1990 period, we used the precipitation and temperature regimes of the 1970-1984 period with annual averages of 474mm and 5.0°C.

- For a favorable scenario, we selected the 1976-1980 period which shows the highest 5-year precipitation average (498 mm) of our 65-year record.

- For an unfavorable and least likely scenario, we have chosen the 5-year period 1961-1965 which averaged 438 mm, the lowest of the last 25 years. 25X1

Selection of Fertilizer Deliveries Scenarios

After a four-year lull in the mid-seventies, fertilizer deliveries to agriculture regained their upward momentum after 1979, growing at an average rate of 1.4 million tons per year to a record 23 million tons in 1983. Such a continued rate of growth (approximately 6 percent per year) in fertilizer deliveries during the next six years would fulfill Soviet plans to deliver 30-32 million tons of fertilizer for crops to agriculture in 1990.[5] 25X1

Based on the Soviets' past performance, we developed three fertilizer delivery scenarios.

- For the high or best case scenario, we adopted an annual 6 percent increase in fertilizer delivery. Although this is the present rate of growth, we doubt that the Soviets will be able to maintain this rate due to expected lags in the commissioning of new facilities for the production of fertilizers, poor management, and the underutilization of existing facilities.

- For our medium, or most likely scenario, we estimate that deliveries would increase by about 0.9 million tons per year, or a 4 percent growth, yielding a total delivery to

5 From Brezhnev's statement at the CPSU Central Committee Plenum on the Food Program, May 1982. 25X1

agriculture of 29 million tons by 1990.

- For our low fertilizer growth scenario, we used 2 percent per annum growth rate. This rate was derived from a model[6] using the last 10 years' deliveries of fertilizer to agriculture. The model results project a total delivery of 26 million tons by 1990 for an increase of only about 0.43 tons per year.

The projected fertilizer deliveries to agriculture for the entire USSR for the three scenarios described above were translated to fertilizer delivery rates (kg/ha) for each Republic by dividing by agricultural area. In all cases, we assume harvested area will approximate 124 million hectares, roughly equal to the annual average hectarage for 1979-83. [redacted] 25X1

Projected Yields and Production

Grain yields and production to 1990 were calculated with the regression model using the three fertilizer scenarios and the actual weather variables for 1961-1965, 1976-1980, and 1970-1984 to project grain yields typical of unfavorable, favorable, and most likely weather scenarios (Table 2). [redacted] 25X1

The model forecasts that, given what we consider the most likely weather and fertilizer scenario, the USSR's average grain yield during 1986-1990 will be 15.7 centners per hectare (ce/ha). Using a harvested area of 124.4 million hectares, this equates to an average annual production of 195 million tons. Given this scenario, the model projects that there is a 95 percent probability[7] that Soviet grain production during 1986-1990 will average between 180 million and 210 million tons. [redacted] 25X1

With a favorable weather scenario similar to 1976-1980 and the high fertilizer delivery levels that the Soviets are striving to achieve, Moscow could average 17.8 ce/ha or 221 million tons, with a 95% probability that the average will be more than 206 million tons but less than 236 million tons. [redacted] 25X1

An unfavorable weather scenario typical of 1961-1965 (the least likely of the three scenarios to occur) and low fertilizer deliveries growth rates could plunge average grain production to

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6 A best fit regression technique was used to make these calculations. [redacted] 25X1

7 The 95% probability range is approximately defined by the model's estimate ± two standard errors of estimate, or within 15 million tons of the projected average of 195 million tons. One standard error of estimate was calculated to be 7.5 million tons. [redacted] 25X1

165 million tons, with less than a 5% probability that it would be above 180 million tons. 25X1

Appendix

A Simple Regression Model for Estimating Grain Yields of the USSR

The purpose of deriving a grain yield regression model is to estimate grain yields during the 1986-90 period under different weather and technology growth scenarios. The model, therefore, has to be a function of variables which measure the contribution of weather and technology to grain yields. [redacted] 25X1

Figure 6 illustrates the historical all-grain yields, total precipitation in the grain area during the growing period (October-August), and the average amount of fertilizer (kg/ha) delivered to agriculture in the USSR. The graph shows a considerable increase in yields from the mid-sixties to the late seventies, with simultaneous increases in fertilizer delivery and levels of precipitation. With a few exceptions, there is a general correspondence between high and low points of precipitation and yield. Thus, precipitation and fertilizer delivery rates are likely candidates for describing grain yields by means of a regression equation. [redacted] 25X1

Because of the paucity of published Soviet grain data since 1975, our grain yield equations were derived for large areas covering one or more Republics and having sufficient climatic stations to adequately describe weather parameters. For example, from 1975-80 only Republic grain yields were published by the Soviets; after 1980 practically no grain yield information was published. [redacted] 25X1

We used the RSQUARE procedure of the Statistical Analysis System (SAS) computer software package to narrow down the selection of variables for the predictive model. The RSQUARE procedure performs all possible regressions for a dependent variable (grain yield, in this instance) and a collection of independent variables, and gives the r-square value for each model. With the selected parameters, we then derived the yield equations using the General Linear Model (GLM) procedure of SAS. [redacted] 25X1

Table 3 lists the variables tested by the RSQUARE routine and the equations finally adopted.[8] An interesting result of the selection process was that fertilizer delivery rates variable (FERTH) produced higher r-squares than the variable YEAR, a term traditionally used as a surrogate for technology.[9] Fertilizer application rates to grain area would be an even better parameter to use in the regression, but these data are not generally available at the Republic level. We found no improvement in estimating Soviet all-grain yields by using separate winter and spring grain yield equations. We therefore elected to use the all-grain yield equations for the combinations of Republics shown in Table 3, which also gave better results than one single equation derived for the entire Soviet Union. 25X1

The major assumptions inherent in the use of the regression model for forecasting grain production in the 1986-1990 period are:

- o That projected increases in fertilizer deliveries represent the major contribution of technology to grain yield increases.

- o That any changes in the mix of grains planted, or in other agricultural practices such as the amount of cropland under irrigation, will take place gradually over time and therefore will be included in the model variable representing the delivery of fertilizer per hectare of agricultural land (FERTH).

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[8] We tested three variables for describing the technology contribution to yield: Year, total fertilizers delivered to agriculture (FERTD), and average fertilizers delivered per hectare of agricultural land (FERTH) from Soviet published data. We also tested cross terms such as FERTH*PREC to detect any interaction between fertilizer response and precipitation amounts, and non-linear terms such as log (FERTH) to describe diminishing yield returns at high fertilizer applications levels. In all instances, except one, we found no significant increase in r-square when crossterms or other non-linear terms were added to the candidate models. Only in Belorussia and in the Baltics, where fertilizer application levels are among the highest in the country, did we find that the use of a log (FERTH) term produced significantly higher r-squares. 25X1

[9] Fertilizer delivered per hectare of agricultural land (FERTH) have increased nearly linearly with time (FERTH and YEAR show a correlation coefficient of 0.98). Therefore FERTH, in addition to being directly related to grain yield increases, is also a surrogate for other technological improvements which have gradually been introduced during the last 25 years and have also been responsible for grain yield increases. 25X1

- That the mean square error of our regression model adequately describes the errors of the model. 25X1

Figure 7 and Table 4 show how the model's estimated yields compare with the actual yields for the year 1960-1980, the period used to derive the model. Also plotted on Figure 7 are the model estimates for 1981-1984 compared to CIA estimates. The model fits the observations with an average error of 1.1 ce/ha and a mean square error of 1.4 ce/ha for individual years and 0.6 centners per hectare (ce/ha) for a 5-year period.[10] The model is able to explain 80 percent of the variation in the all-grain yields. 25X1

The model's errors may be caused by a combination of factors. The first is the gross nature of the model itself. Because of paucity of data, it has to use meteorological variables averaged for relatively long periods (4 to 10 months) and for very large areas (as large as the RSFSR). Second, although the years used in the model (1960-1980) are the most relevant in terms of describing recent Soviet agricultural and climate changes, they may not be sufficient to capture the range of errors inherent in the model. Third, the variables in the model may be related to yield in a more complex, non-linear and interactive way than represented by our simple linear model. Finally, there are certainly other variables such as short-term weather events which influence yield but could not be included in the model. 25X1

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10 The mean square error for a 5-year period is $1.4/\sqrt{5} = 0.6$. Three years (1971, 1973, and 1976) show particularly large model errors of the order of 2-3 ce/ha. An investigation of the causes of these large errors will be performed by AAB in the coming months. 25X1

PRECIPITATION (mm)

OBS	YEAR	PREC21		PREC36		[illegible]	
1	1920	375		.		.	
2	1921	335		.		.	
3	1922	443	(394)	.		.	
4	1923	413		.		.	
5	1924	402		.		.	
6	1925	388		.		.	
7	1926	470		.		.	
8	1927	429	(433)	.		.	
9	1928	491		.		.	
10	1929	389		.		.	
11	1930	431		.		.	
12	1931	412		.		.	
13	1932	417	(425)	.		.	
14	1933	459		.		.	
15	1934	405		.		.	
16	1935	403		.		.	
17	1936	369		.		.	
18	1937	433	(385)	.		.	
19	1938	359		.		.	
20	1939	363		.		.	
21	1940	415		.		.	
22	1941	472		.		.	
23	1942	429	(421)	.		.	
24	1943	383		.		.	
25	1944	406		.		.	
26	1945	404		.		.	
27	1946	393		.		.	
28	1947	419	(407)	.		.	
29	1948	422		.		.	
30	1949	396		.		.	
31	1950	442		449		448	
32	1951	351		376		377	
33	1952	385	(406)	400	(413)	412	(419)
34	1953	446		452		455	
35	1954	405		390		400	
36	1955	442		443		438	
37	1956	478		471		466	
38	1957	426	(445)	420	(442)	414	(441)
39	1958	480		481		487	
40	1959	397		393		399	
41	1960	437		456		457	
42	1961	479		462		461	
43	1962	459	(444)	430	(443)	439	(449)
44	1963	418		407		417	
45	1964	423		459		469	
46	1965	402		395		402	
47	1966	505		540		516	
48	1967	454	(454)	459	(463)	451	(453)
49	1968	453		458		444	
50	1969	454		463		450	
51	1970	606		585		547	
52	1971	478		462		468	
53	1972	438	(487)	425	(478)	441	(474)
54	1973	453		474		465	
55	1974	459		448		447	
56	1975	.		401		.	
57	1976	.		462		.	
58	1977	.		490	(478)	.	
59	1978	.		545		.	
60	1979	.		494		.	
61	1980	.		498		.	
62	1981	.		470		.	
63	1982	.		489	(470)	.	
64	1983	.		464		.	
65	1984	.		432		.	

TEMPERATURE (°C)

1	1920	5.3		.		.	
2	1921	4.6		.		.	
3	1922	4.5	(4.9)	.		.	
4	1923	4.9		.		.	
5	1924	5.4		.		.	
6	1925	6.0		.		.	
7	1926	4.6		.		.	
8	1927	5.0	(4.6)	.		.	
9	1928	3.5		.		.	
10	1929	3.8		.		.	
11	1930	5.1		.		.	
12	1931	4.1		.		.	
13	1932	5.2	(4.5)	.		.	
14	1933	4.2		.		.	
15	1934	4.1		.		.	
16	1935	5.0		.		.	
17	1936	4.8		.		.	
18	1937	5.4	(5.2)	.		.	
19	1938	5.7		.		.	
20	1939	5.1		.		.	
21	1940	4.3		.		.	
22	1941	4.0		.		.	
23	1942	2.7	(4.3)	.		.	
24	1943	4.7		.		.	
25	1944	5.8		.		.	
26	1945	3.5		.		.	
27	1946	5.0		.		.	
28	1947	3.8	(4.6)	.		.	
29	1948	5.7		.		.	
30	1949	5.2		.		.	
31	1950	4.3		4.7		4.7	
32	1951	4.9		4.9		4.9	
33	1952	4.9	(4.5)	4.8	(4.6)	4.8	(4.5)
34	1953	4.8		4.8		4.8	
35	1954	3.2		3.6		3.5	
36	1955	5.2		5.1		5.1	
37	1956	3.3		3.7		3.7	
38	1957	5.3	(4.8)	5.1	(4.8)	5.1	(4.8)
39	1958	4.8		4.7		4.7	
40	1959	5.3		5.2		5.2	
41	1960	3.6		3.9		3.9	
42	1961	5.4		5.4		5.4	
43	1962	5.8	(4.9)	5.6	(4.8)	5.7	(4.8)
44	1963	4.8		4.8		4.8	
45	1964	4.7		4.3		4.4	
46	1965	5.3		4.9		5.1	
47	1966	5.6		5.4		5.5	
48	1967	4.7	(4.7)	4.5	(4.6)	4.8	(4.7)
49	1968	5.3		5.2		5.3	
50	1969	2.7		2.9		2.7	
51	1970	4.9		4.8		5.0	
52	1971	4.7		4.6		4.6	
53	1972	5.1	(5.0)	4.9	(4.9)	4.7	(4.9)
54	1973	5.4		5.2		5.0	
55	1974	5.1		5.0		5.1	
56	1975	.		6.4		.	
57	1976	.		3.6		.	
58	1977	.		4.2	(4.7)	.	
59	1978	.		4.7		.	
60	1979	.		4.6		.	
61	1980	.		4.1		.	
62	1981	.		5.8		.	
63	1982	.		5.2	(5.4)	.	
64	1983	.		5.5		.	
65	1984	.		5.3		.	

Table 1. Precipitation and temperature averages for the USSR grain area. Values in parentheses are 5-year averages.

Table 2

USSR: All-grain average yields and production estimated for the 1986 - 1990 period with three different climate and fertilizer scenarios

Increase in Fertilizer Deliveries to Agriculture[1]	Yields (ce/ha)	Average Production (m tons)[2]	Range of Production 95% Probability[3]
	Unfavorable Weather Scenario		
Low	13.3	165	150 - 180
Medium	13.6	169	154 - 184
High	14.2	177	162 - 192
	Favorable Weather Scenario		
Low	16.8	209	194 - 224
Medium	17.2	214	199 - 229
High	17.8	221	206 - 236
	Most Likely Weather		
Low	15.3	190	175 - 205
Medium	15.7	195	180 - 210
High	16.2	202	187 - 217

[1] Low, medium, high increases in fertilizer deliveries to agriculture correspond to approximately 2, 4, and 6 percent increases per year.

[2] Production is estimated by assuming an average grain area of 124 million hectares, similar to the 1979 - 1983 period.

[3] The 95% probability range is approximately defined by the average ± 2 standard errors of estimate.

25X1

Approved For Release 2009/09/15 : CIA-RDP85T01058R000303750001-8

Table 3

Variables Tested By The RSQUARE Procedure to Develop a Yield Regression Model

$PREC_{(4-9)}$	$PREC_{(10-3)}$	$PREC_{(10-9)}$	$PREC_{(10-8)}$	$PREC_{(4-7)}$
$TEMP_{(4-9)}$	$TEMP_{(10-3)}$	$TEMP_{(10-9)}$	$TEMP_{(10-8)}$	$TEMP_{(4-7)}$
FERTD	LOG(FERTD)	SQRT(FERTD)		
FERTH	LOG(FERTH)	SQRT(FERTH)		
YEAR	$YEAR^2$			
(FERTH)x(PREC)				

EQUATIONS SELECTED For Estimating All Grain Yields

			R^2
(1)	RSFSR	: $YIELD_r = -3.97 + 0.0875\ PREC_{(4-7)} + 0.0141\ FERTH$	0.80
(2)	KAZAKHSTAN	: $YIELD_k = 3.52 + 0.0472\ PREC_{(10-8)} - 0.5367\ TEMP_{(4-7)} + 0.1277\ FERTH$	0.73
(3)	UKRAINE + MOLDAVIA	: $YIELD_u = 25.44 + 0.0313\ PREC_{(4-9)} + 1.334\ TEMP_{(10-3)} - 1.156\ TEMP_{(4-7)} + 0.0544\ FERTH$	0.81
(4)	BELORUSSIA + BALTICS	: $YIELD_b = -15.069 - 1.1584\ TEMP_{(4-7)} + 9.519\ LOG(FERTH)$	0.83

(5) $YIELD_p = (A_r\ YIELD_r + A_k\ YIELD_k + A_u\ YIELD_u + A_b\ YIELD_b)/A_t$

where A_r, A_k, A_u, A_b are the grain areas, and $A_t = A_r + A_k + A_u + A_b$

(6) USSR : $YIELD = -1.472 + 1.104\ YIELD_p$ 0.80

PREC - average region precipitation in mm weighted by grain area.
TEMP - average region temperature in °C weighted by grain area.
FERTD - total fertilizer delivered to agriculture in million tons.
FERTH - average fertilizer delivered per hectare of agricultural land, in kg.
$YIELD_r$ - average region grain yield of major grain area in centners per hectare.

NOTE: Subscripts refer to first and last months of period averaged for temperature (TEMP), or totaled for precipitation (PREC). For example, $PREC_{(10-3)}$ refers to total precipitation during October-March.

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Table 4

USSR: All Grains Yields and Production,
Actual and Model Estimates, 1960 - 1984

Year	Actual Yield Ce/ha	Production Million Tons	Model Yield Ce/ha	Production Million Tons
1960	10.9	125.5	11.9	137.5
1961	10.7	130.8	11.6	141.8
62	10.9	140.2	10.7	137.7
63	8.3	107.5 (130.3)**	8.5	110.4 (133.7)
64	11.4	152.1	11.2	149.3
65	9.5	121.1	10.1	129.3
66	13.7	171.2	14.4	179.7
67	12.1	147.9	12.2	149.0
68	14.0	169.5 (167.5)	14.8	179.8 (169.4)
69	13.2	162.4	12.6	154.6
1970	15.7	186.8	15.4	183.7
71	15.4	181.2	13.5	159.2
72	14.0	168.2	12.9	155.1
73	17.6	222.5 (181.6)	14.2	180.0 (167.0)
74	15.4	195.7	14.7	187.0
75	11.0	140.1	12.0	153.5
76	17.5	223.8	15.5	198.1
77	15.0	195.7	15.7	204.6
78	18.5	237.4 (205.5)	18.5	237.7 (208.8)
79	14.2	179.2	15.6	197.1
1980	14.9	189.1	16.3	206.3
81	*	*	13.0	163.3
82	*	*	15.9	195.5
83	*	*	16.3	196.9
84	*	*	14.5	173.3

* Soviets did not report grain yield and production after 1981.

** Values in parentheses are 5-year averages.

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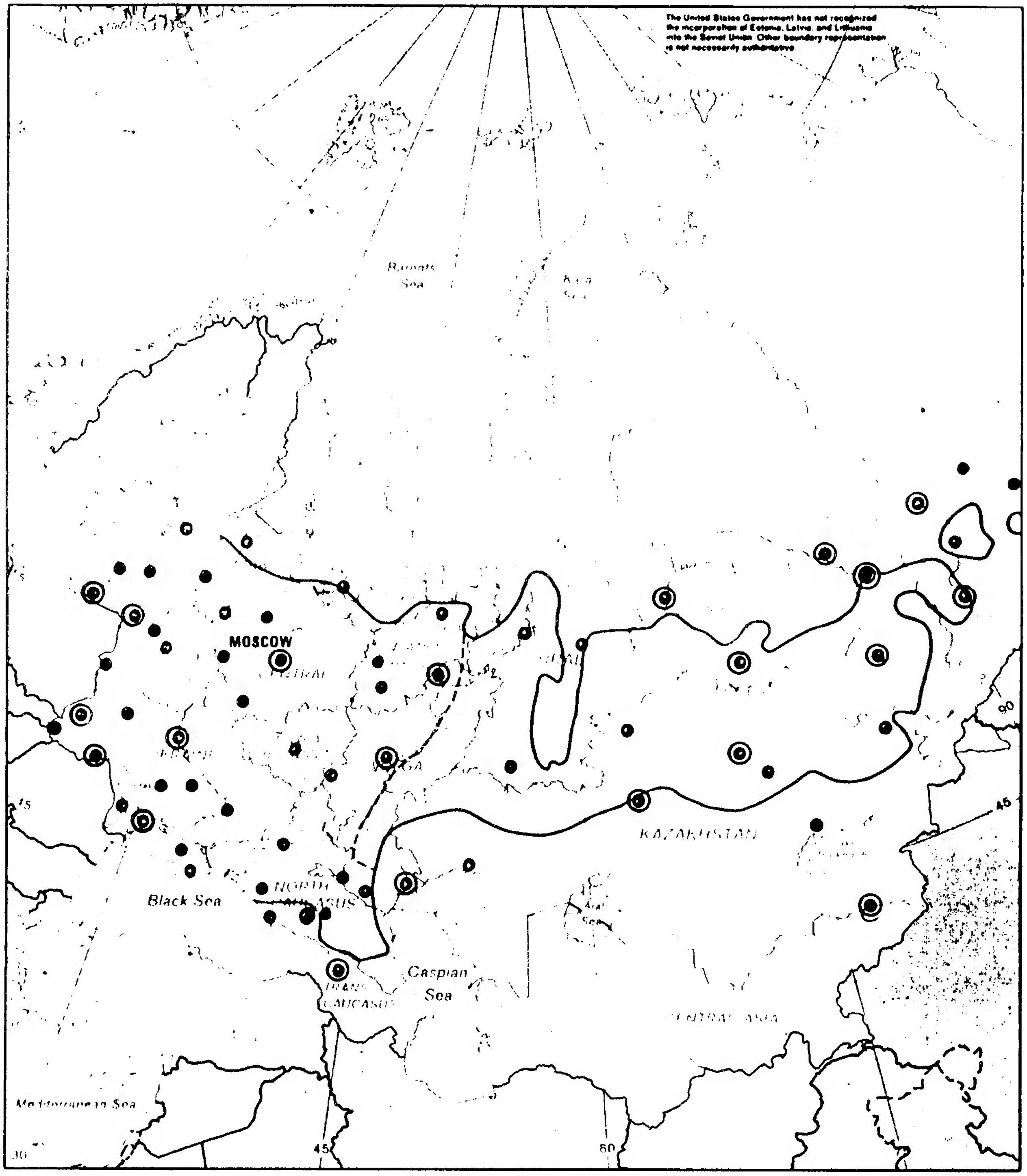

Length of climatic record:

- ◎ 1920 - 1974
- o 1951 - 1984
- ● 1951 - 1974

Figure 1. Location of climatic stations in and around major grain area. 25X1

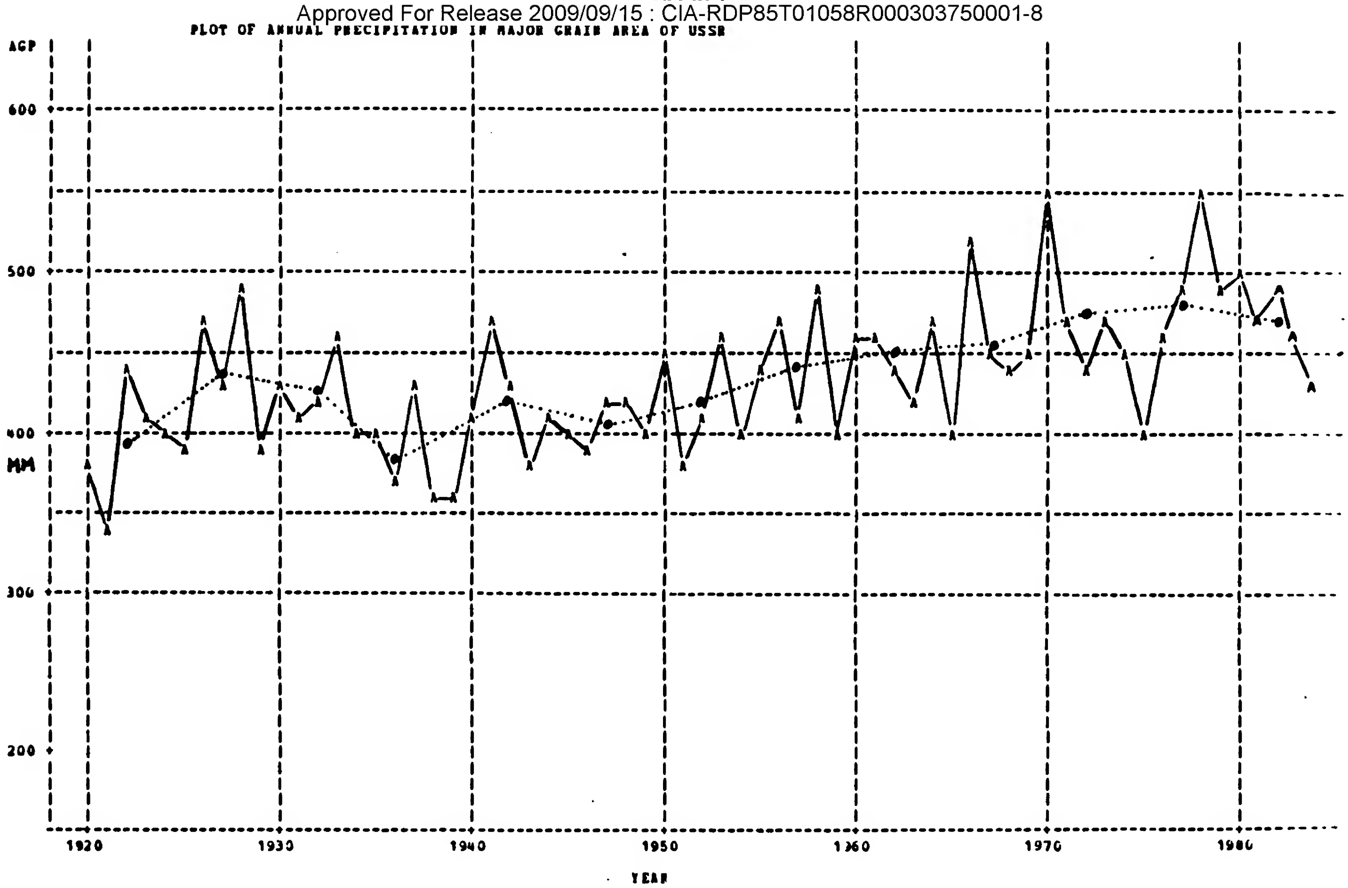

Figure 2. Annual average of precipitation (Oct - Sept) for the Soviet grain area. Dots joined by dashed lines represent 5-year averages. 21 stations, 66 stations, 36 stations averages were used respectively for the periods 1920 - 1949, 1950 - 1974, and 1975 - 1984. 25X1

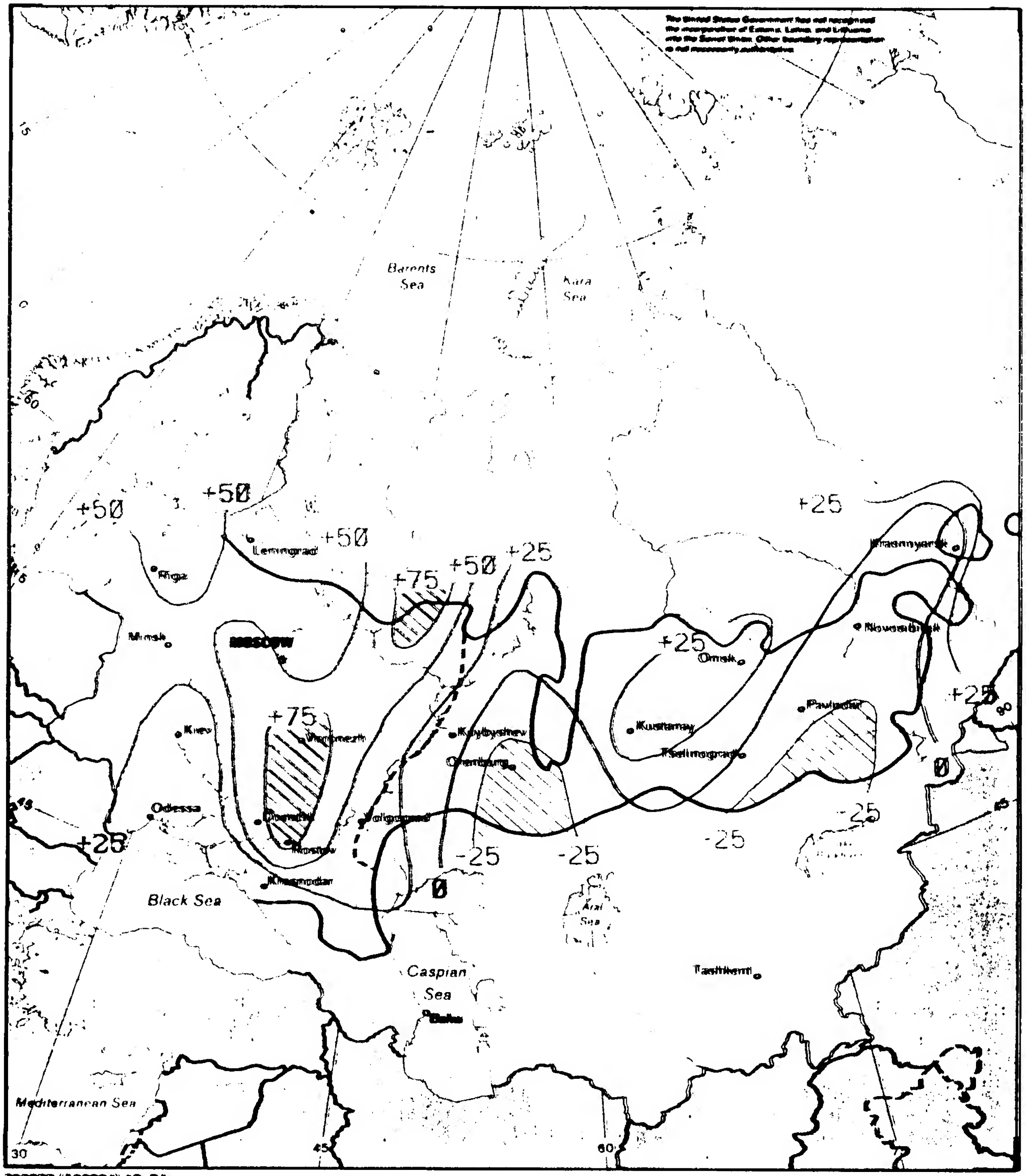

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Figure 3. Change in mean annual precipitation (mm) for the period 1975 - 1984 compared to the period 1950 - 1974. 25X1

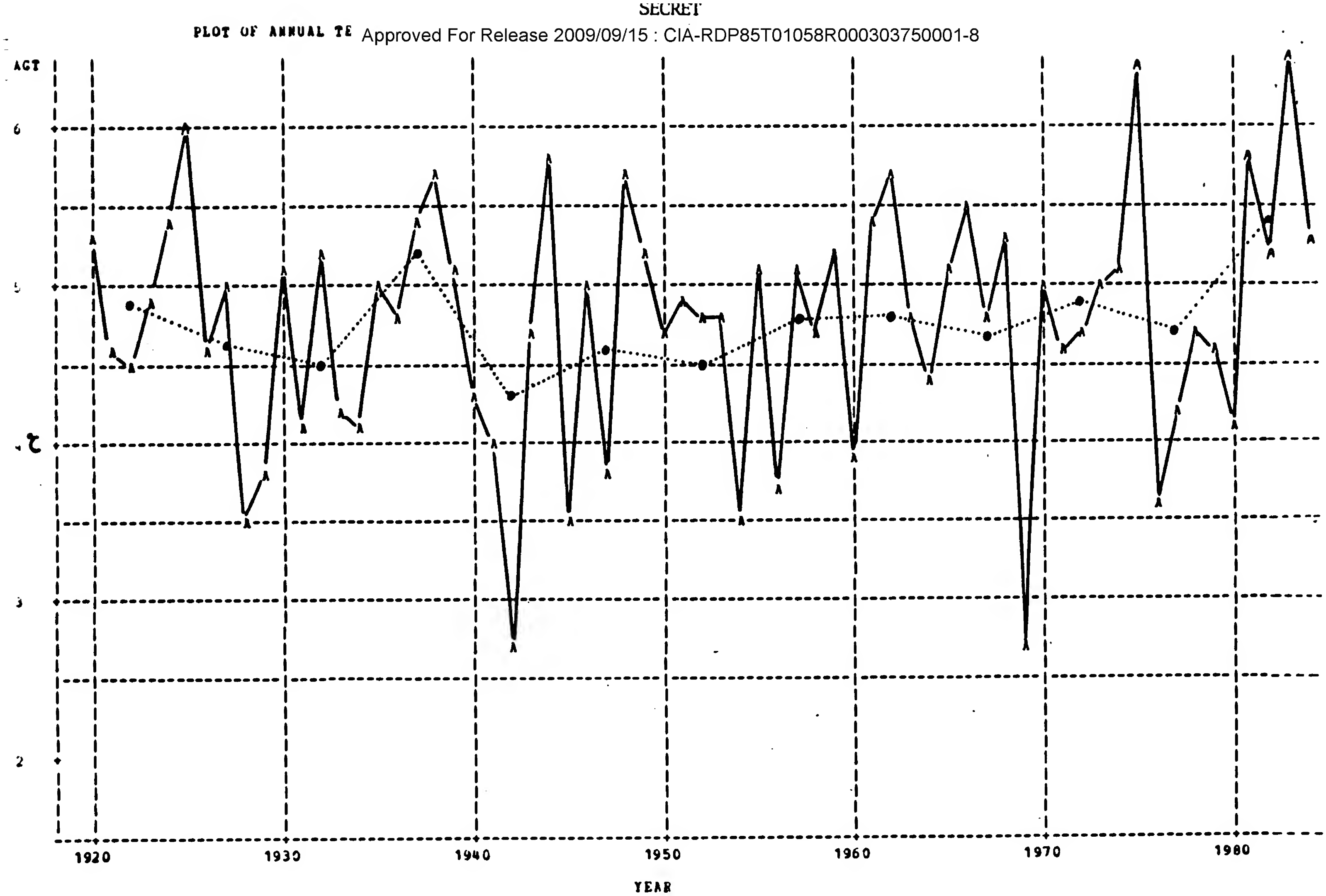

Figure 4. Annual average temperature (Oct - Sept) for the Soviet grain area. Dots joined by dashed lines represent 5-year averages. 21 stations, 66 stations, 36 stations averages were used respectively for the periods 1920 - 1949, 1950 - 1974, and 1975 - 1984. 25X1

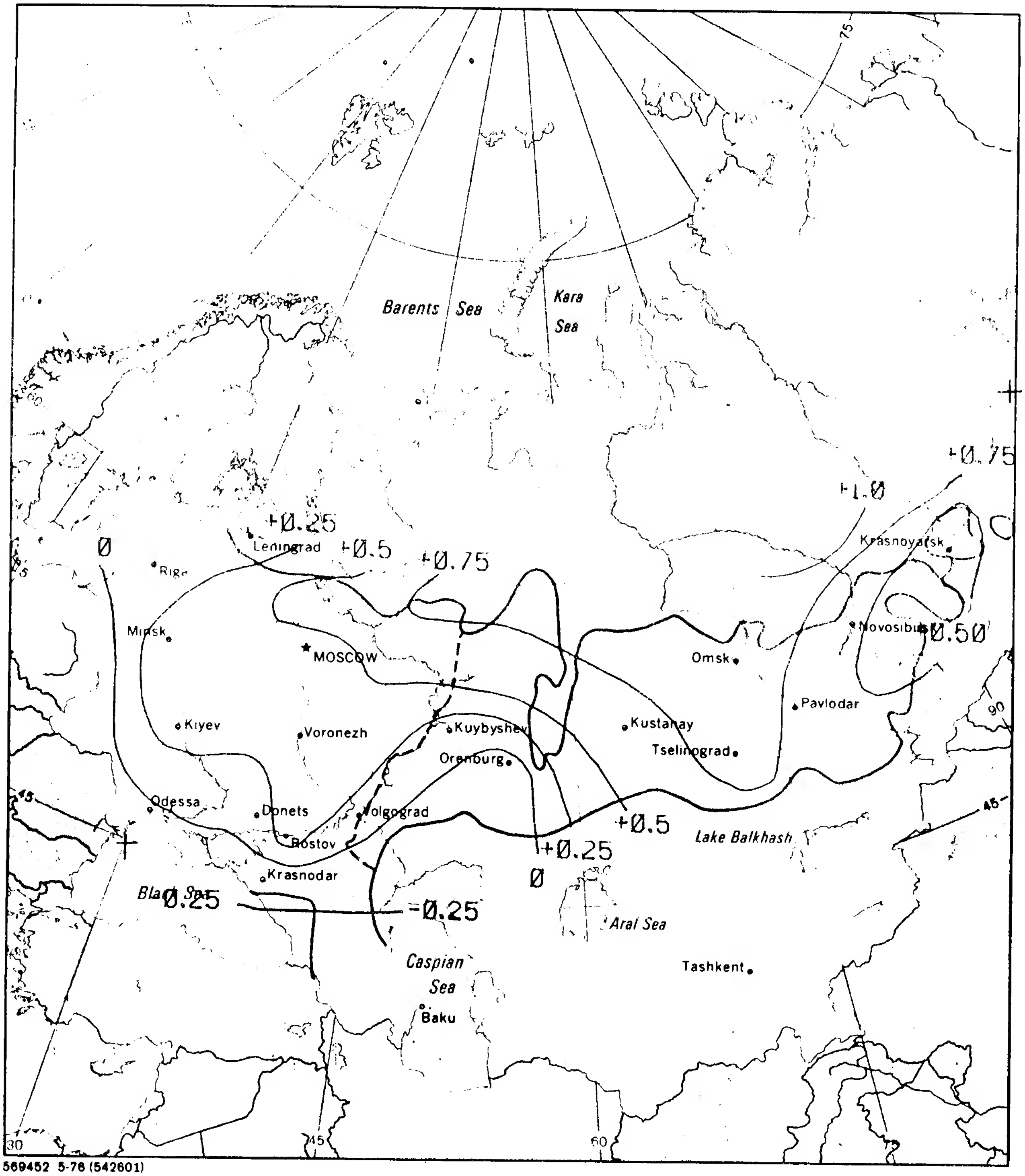

Figure 5. Change in mean annual temperature (°C) for the period 1975 - 1984 compared to the period 1950 - 1974.

25X1

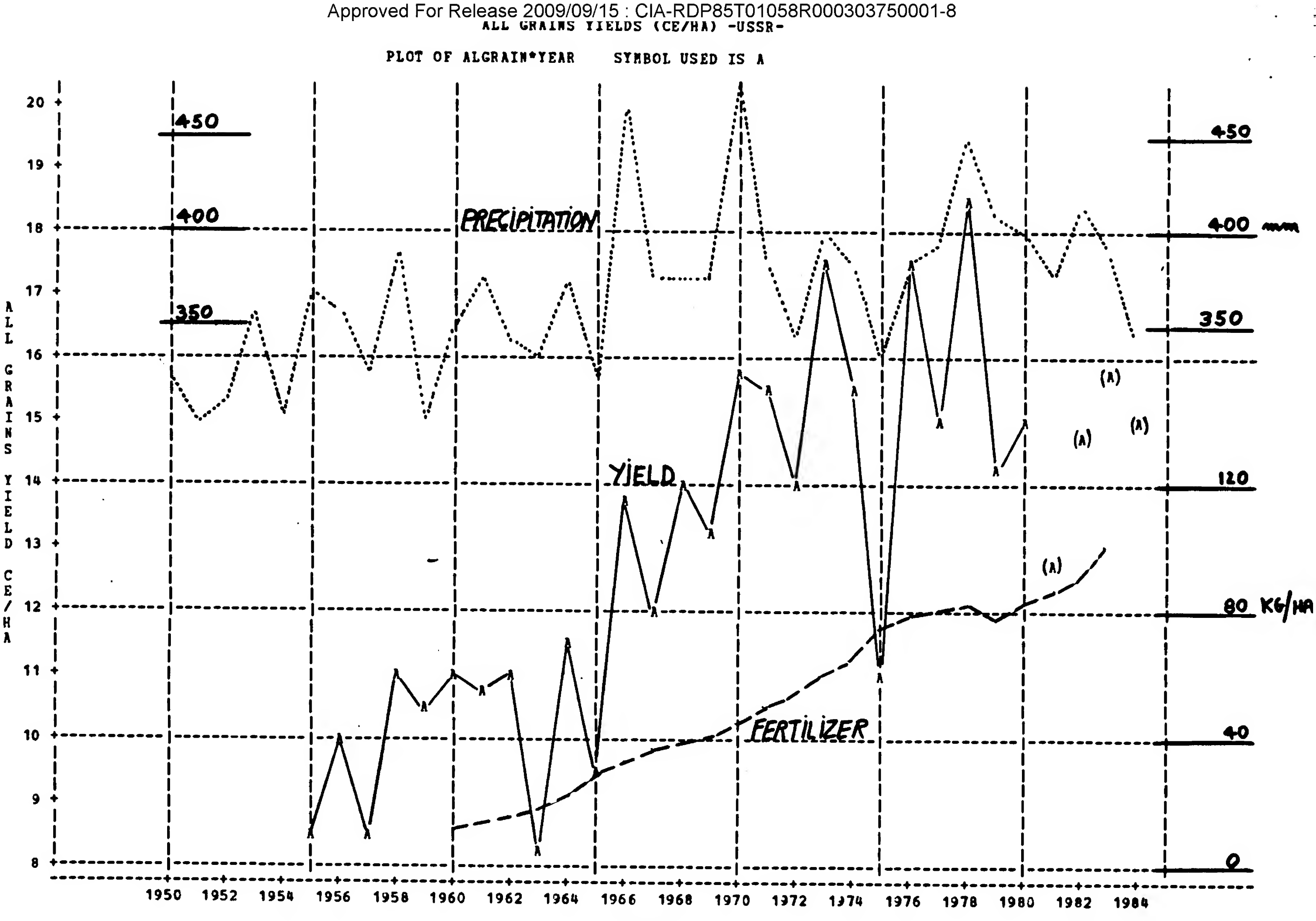

Figure 6. Growing period (October - August) precipitation for the Soviet grain area, all grain yields, and average fertilizer delivered per hectare of agricultural land. All grain yields after 1980 (A) are CIA estimates. [redacted]

25X1

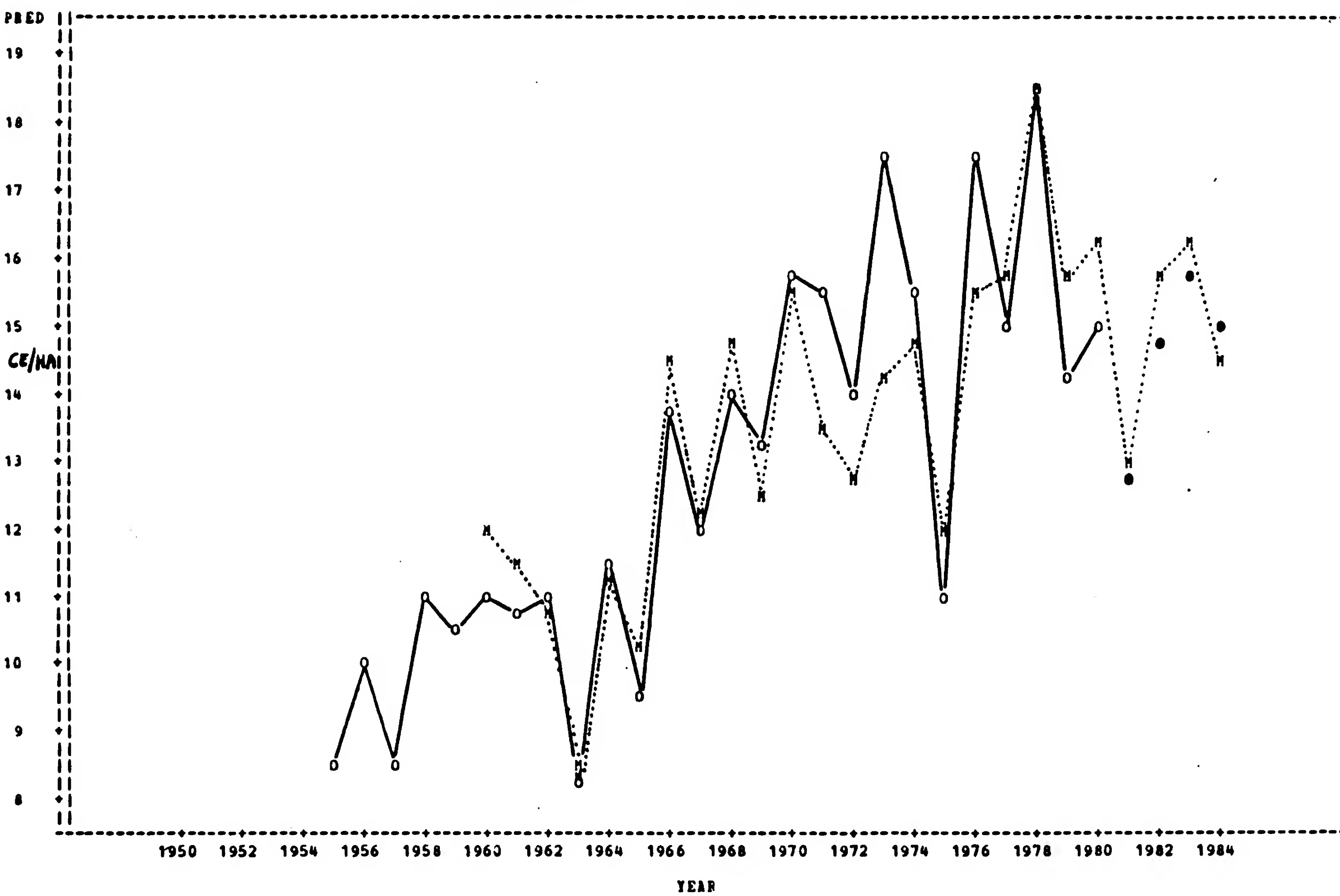

Figure 7. Comparison of observed all-grain yields (O) and model's yield (M). After 1980 the model's yields are compared with the AAB yield estimates shown as dots.

25X1

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